


Breaking up prolonged sitting with a 6 min walk improves executive function in women and men esports players: a randomised trial

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ABSTRACT

Objective The effect of prolonged sitting on executive function and performance in competitive esports players are unknown. This study aimed to evaluate executive function following a 6 min bout of walking or rest during prolonged gaming in competitive esports players.

Methods 12 men and 9 women completed three separate 2-hour gaming session days assigned in randomised order consisting of a 6 min walk break, 6 min rest break and continuous before and after each session. Postintervention participant exit survey data were also collected.

Results The walk condition produced a significantly faster mean solution time (7613.6±3060.5 min, p=0.02) and planning time (5369.0±2802.09, p=0.04) compared with the resting condition (9477±3547.4; 6924±3247.7) and continuous play (8200.0±3031.6; 5862.7±2860.7). The rest condition resulted in the slowest mean solution time (9477.0±3547.4) and planning time (6924.0±3247.7), with the continuous play resulting in a faster mean solution time (8200.1±3031.6) and planning time (5862.7±2860.7) than the rest condition. There was no impact on game performance in any of the conditions. However, over 70% of participants felt that the walk break improved esports performance.

Conclusions Reducing sit time and breaking up prolonged sitting have acute and chronic health benefits. This study provides evidence that a 6 min walking break in the middle of 2 hours of gameplay allows gamers to have these health benefits while improving processing speed and executive function.

Trial registration number NCT04674436.

INTRODUCTION

Video gameplay is harmonious with prolonged bouts of sitting. Although players are seated for prolonged periods and do not experience the physical demands that are seen in conventional sports, competing in video games (ie, esports) can be quite physically and mentally demanding in other ways. Players can perform up to 500 actions per minute (ie, keyboard or mouse inputs) while simultaneously focusing at a level of attention

Key messages

What is already known

- ▶ Esports players are required to sit for prolonged bouts in order to practice and compete.
- ▶ Prolonged sitting may impair executive function and can have dangerous health implications in esports players as young as 12 years old.
- ▶ Many preventive measures are not well accepted or practised by esports players, coaches or stakeholders across all levels of competition.

What are the new findings

- ▶ A light-intensity 6 min walking break following an acute 1-hour session of competitive gaming improves executive function and processing speed in competitive players.
- ▶ A resting 6 min break following 1-hour acute session of competitive gaming decreased executive function speed in players.
- ▶ Over 70% of highly competitive gamers who participated preferred the walking break and reported it 'positively helped' them compared with a resting break.

that results in significant cognitive stress and high variance of physiological parameters.¹⁻⁴ In conjunction with the cognitive stress, players may suffer from the corresponding harmful health effects of prolonged sitting. These include acute health risks such as deep vein thrombosis (DVT), which can be life-threatening if the thrombosis travels to the lungs and creates a pulmonary embolism (PE).⁵⁻⁷ Aside from the acute health risks, the chronic health effects of repeated prolonged sitting are correlated with cardiometabolic risk factors and early mortality.^{8,9}

In addition, prolonged sitting acutely disrupts cerebral blood flow and may reduce oxygen supply to the brain.¹⁰ This disruption in neuronal metabolism can lead to mental fatigue, impaired cognition and reduced



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executive function.^{11–13} The relationship between prolonged gaming, executive function and physical breaks has not been thoroughly investigated. Recently, Sousa *et al* found a decrease in executive function in high-level gamers following 2.5 consecutive hours of competitive gameplay regardless of physical activity levels.¹¹

This current study set out to expand on these findings and to evaluate executive function changes following a short active break (6min walking) as compared with a short passive break (6min resting) in competitive first-person shooter (FPS) esports players during 2 hours of gameplay. The primary outcome was to evaluate executive function changes. Secondary outcomes included gaming performance as well as players' perceptions.

METHODS

Design and setting

This study was a randomised repeated measures experimental design and it was registered on clinicaltrials.gov. Due to the global COVID-19 pandemic, the study was conducted virtually with each participant. This allowed participants to use their own computers. Participants communicated with researchers via Zoom, Google Hangouts, texting and Discord. All of these platforms allow for video and chat communication except for texting through a non-social media platform.

Sample

Twenty-one participants (12 men and 9 women), 20.76 years (SD=2.61), from seven different countries, participated in this study. Men averaged a body mass index (BMI) of 20 (1.4) and women averaged a BMI of 21.9 (3.4). One subject identified as a transgender woman and had been taking hormone replacement therapy for over 1 year and was included in the analysis as such (figure 1).

Subjects were recruited online via groups and servers on Facebook, Twitter, Twitch and Discord. Twitch is the largest streaming platform for gamers, and Discord allows easy communication through voice, video, chat, text and is very popular among gamers. All subjects

signed electronic consent, and study data were collected and managed using REDcap (Research Electronic Data Capture, Vanderbilt University, Nashville, TN) tools hosted at NYIT. REDcap is a secure, web-based application designed to support data capture for research.¹⁴ Participant inclusion criteria were: (1) women or men 18–30 years of age and (2) play FPS games with over 500 hours of game time. Exclusion criteria were: (1) no competitive FPS ranking, (2) colour blindness and (3) hand injury within the last year or chronic wrist pain (table 1).

Statistical analysis

IBM SPSS V.27 was used to carry out all statistical analyses. A priori sample size calculations revealed that 20 subjects were required to detect observed differences at a power of 80%. Statistical significance for this study was set at the $p < 0.05$. To compare neuropsychological and esports performance outcomes across our three conditions, we used the General Linear Model in SPSS to compare outcomes among the conditions. Additionally, we examined any potential gender interactions.

Data collection

Data were collected on 4 separate days with at least 24 hours between each day. Following consent, participants performed a practice test of the online outcome measures to familiarise themselves on the first day. This was followed by 3 intermittent days of participant FPS gameplay that each lasted 120–135 min (2 hours±15 min) each. The 3 days consisted of (1) continuously gameplay for 120–135 min with no break, (2) a 6 min walking break with 60–75 min of gameplay before and after, (3) a 6 min supine resting break with 60–75 min of gameplay before and after (figure 2). The intervention order was randomised across participants using a Latin square design.¹⁵ The 15 min window for gameplay was to allow for participants to finish any active game. This was done by texting the subjects 10 min before the 60 min marker and 10 min before the 120 min marker. Subjects were told to finish the current game and text the investigator as soon as the game was finished. This did not impact on our study as all games were able to be completed within the time frame set. Furthermore, subjects were asked to try and maintain a similar diet on all testing days and to eat within the same time frame prior to playing for each testing day. Diets consisted predominantly of small snacks and sandwiches prior to gaming.

The 6 min break was based on findings by Christmas *et al*, who found a 3 min walking break at 30 min improved attention and executive function.¹⁶ Breaking up an esports game every 30 min is not reasonable. Therefore, we chose to break at 60 min of play using the cumulative break time of 6 min. All participants were required to play using the same FPS game title, same gaming setup and not change any equipment they used in previous sessions. All data were collected within the same time of day across sessions.

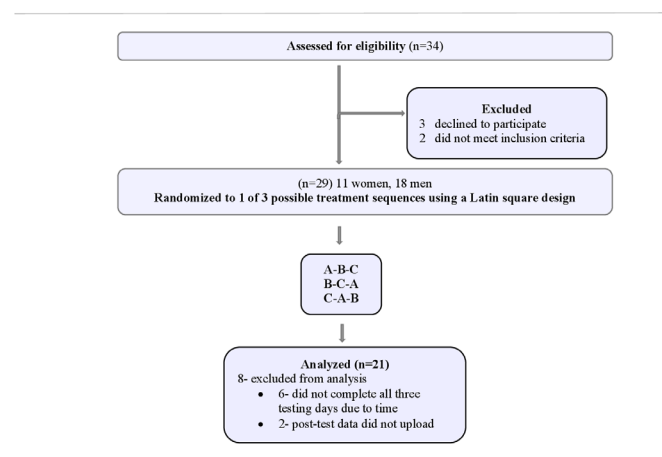


Figure 1 Study flow diagram.

Table 1 Demographic data

Men	n=12	Women	n=9
Age (SD)	20 (1.4)	Age (SD)	22 (3.4)
Weight (kg) (SD)	85.7 (27.8)	Weight (kg)	66.2 (11.8)
Height (in) (SD)	70 (1.4)	Height (in)	66.1 (2.7)
BMI (SD)	20 (1.4)	BMI	21.9 (3.4)
Current residence (%)		Current residence (%)	
United States	66	United States	56
Netherlands	8	Canada	11
France	8	Sweden	11
England	18	Finland	33
Education level (%)		Education level (%)	
High school	33	High school	44
Associates degree	8	Associates degree	0
Current bachelor's student	33	Current bachelor's student	34
Bachelor's degree	26	Bachelor's degree	11
Master's degree	0	Master's degree	11
Ethnicity (%)		Ethnicity (%)	
Caucasian	50	Caucasian	67
Asian	42	Asian	22
Prefer not to answer	8	Prefer not to answer	11
Right-handed	85	Right-handed	100
Primary game (%)		Primary game (%)	
Overwatch	33	Overwatch	45
Valorant	33	Valorant	11
Team fortress	9	Fortnite	11
Counter strike	9	Counter strike	11
Rainbow six	9	Halo	22
Apex legends	9		
Hours played weekly (%)		Hours played weekly (%)	
More than 6	100	More than 6	67
5–6 hours weekly	0	5–6 hours weekly	22
3–4 hours weekly	0	3–4 hours weekly	11
Tournament rankings % (varies by game)		Tournament rankings (may varies by game) (%)	
Top 500 globally	15	Top 500 globally	0
Master	15	Master	33
Platinum	7	Platinum	22
Diamond	24	Diamond	0
Gold	7	Gold	22
Silver 3	7	Silver 3	0
Other	24	Other	22

BMI, body mass index.

Day 1

Interested participants were asked to complete an online consent form, demographic form and the International Physical Activity Questionnaire (IPAQ) Long Version¹⁷ in REDcap. Instructions for baseline completion of executive function measures were administered and completed within 2 days of testing for familiarisation. The online executive function tests were administered through

Millisecond Software (Seattle, Washington) remote psychological testing.

Days 2, 3 and 4

Before testing, each participant was connected to a researcher virtually. On completing each gaming session, participants were asked not to leave the gaming station and immediately take the online tests again. After

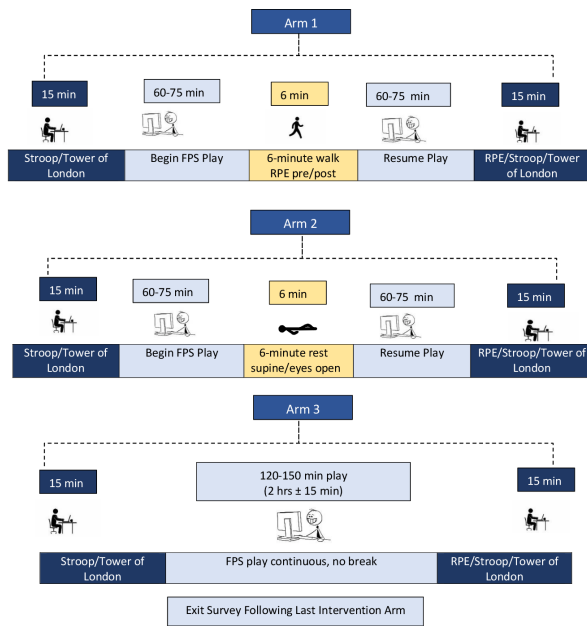


Figure 2 Virtual study protocol. FPS, first-person shooter; RPE, Rating of Perceived Exertion.

completing all three arms, subjects completed a final exit survey through REDcap that focused on perceptions of the effectiveness of each of the three-arm conditions on their gaming performance.

The three arms

The walking intervention

Participants were asked to find a place near their gaming setup that they were able to walk for 6 min on a flat surface back-and-forth while holding their smartphone in their hand to hear the investigators' cues. Before gaming, the investigator instructed the participant to open the testing links and to begin the tests. Once the completed tests were confirmed, the participant logged onto their game and told the investigator when they began. At 55 min, the investigator instructed the participant to finish their current game and alert them when they do. The average time before a break was 1 hour and 7 min (67.4 ± 7.9 min). Each investigator used the same verbiage: 'You will now get up and walk for 6 uninterrupted minutes. You are to walk briskly but comfortable. I will let you know when you are halfway done. After, I will ask you how hard your effort was while walking using the scale between 6–20 that I show you'. The 6–20 Borg Rating of Perceived Exertion (RPE) Scale was shown to the participant via the video conference screen. The Borg scale is a validated scale to measure how hard a person feels they are working during physical activity and has been validated to correlate heart rate and perceived effort during active video game play.¹⁸ The participants then returned directly to gaming. At the 55 min marker, they were instructed to alert the investigator when they completed the current game. The average time of the second gaming segment was 1 hour 7 min (66.5 ± 8.3 min). On completion of gaming, RPE was recorded and the number of wins, losses and kill–death

ratio (KDR) for each game. Following this, participants were instructed to complete the online executive function tests immediately. KDR is an individual FPS player statistic, equal to the number of opponent 'kills' divided by the number of player 'deaths' recorded across an entire game. A KDR of greater than one indicates more kills were recorded than deaths. For example, a player with 23 kills and 16 deaths would have a KDR of 1.44 for that game.

The supine rest intervention

The same procedures used for the walking intervention were followed for the rest intervention, except instead of walking, the participants laid supine for 6 min with their eyes open next to their gaming area. The reason participants kept their eyes open was to avoid any rest of the eyes that was not given while doing the 6 min walk break. The first gaming segment before rest averaged 1 hour 3 min (63.2 ± 3.9), while the subsequent postrest gaming session averaged 1 hour 2 min (62.3 ± 4.7).

The continuous gaming session

Participants were asked to complete the executive functioning measures before playing. Following 115 min, they were to complete their current game. The average gaming time during continuous gaming was 2 hours 5 min (125.3 ± 6.0 min).

Outcome measurements

Colour word Stroop with keyboard (Stroop)

The colour word Stroop is a measure of reaction time, speeded inhibitory control and set switching.¹⁹ The Stroop test was administered online via the Inquisit Lab software, developed by Millisecond Software (Seattle, Washington).

The Tower of London

The Tower of London test is a neuropsychological instrument that measures the executive functioning area of planning and non-verbal problem-solving abilities.²⁰

Exit survey

On completing all three intervention arms, participants were surveyed on how they believed each impacted their gaming performance. As prescribed by Creswell and Poth,²¹ open-response data were first open coded to find primary themes. Then, data were reanalysed via axial coding and finally selective coding to finalise the major themes through cross-referencing the interrelationships of the major coded primary themes.

Patient and public involvement

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

RESULTS

For neuropsychological outcomes, there were significant differences among conditions for the Tower of London

means solution time and planning time. For both of these outcomes, the walking condition produced the fastest solution time (7613.6 ± 3060.5 min, $p=0.02$) and planning time (5369.0 ± 2802.1 , $p=0.04$). The continuous play condition produced the second-fastest solution time (8200.1 ± 3031.6 min) and planning time (5862.7 ± 2860.7 min) and the resting condition produced the slowest solution time (9477.0 ± 3547.4 min) and planning time (6924.0 ± 3247.7 min). There were no significant differences among conditions for neuropsychological outcome variables, including Tower of London total accuracy,

Stroop reaction time and Stroop proportion correct. Ratings of perceived exertion were not significantly different between conditions ($p=0.08$). The percentage of esports games won was not significantly different across conditions ($p=0.6$), nor was KDR ($p=0.8$). There were no significant interactions by participant gender for any of the analysed dependent variables (table 2).

Exit survey findings

As seen in table 3, over 70% of participants perceived that the 6min walk break 'positively helped' gaming

Table 2 Outcome measurements following a walking break, resting break and continuous play

Outcome variable	Women (n=9)	Men (n=12)	Group (n=21)	P value	P value
				By group	Gender interaction
Total accuracy		Number correct (SD)			
Walk	34.2 (1.1)	33.4 (2.3)	33.8 (1.9)		
Rest	34.2 (2.4)	33.4 (2.4)	33.8 (2.4)	0.7	0.9
Continuous	34.3 (1.7)	33.9 (2.7)	34.1 (2.3)		
Mean solution time		Time/ms (SD)			
Walk	7325.5 (1925.2)	7829.7 (3770.3)	7613.6 (3060.5)		
Rest	10098.2 (3625.9)	9011.1 (3573)	9477 (3547.4)	0.02*	0.5
Continuous	8331.9 (4139.4)	8101.1 (2055.2)	8200.1 (3031.6)		
Planning time		Time/ms (SD)			
Walk	5061.7 (1566.9)	5599.5 (3516.1)	5369 (2802.9)		
Rest	7612.2 (3454.3)	6407.9 (3133.9)	6924 (3247.7)	0.04*	0.4
Continuous	6069.6 (3883.9)	5707.5 (1961.3)	5862.7 (2860.7)		
RPE following gameplay		6–20 Borg			
Walk	12.3 (4)	13.1 (2.9)	12.8 (3.3)		
Rest	11.6 (4.3)	11.3 (2.6)	11.4 (3.3)	0.08	0.8
Continuous	12.9 (2.1)	13.4 (2.9)	13.2 (2.5)		
Reaction time incongruent trials		Time/ms (SD)			
Walk	642.1 (99.9)	683.3 (99.4)	665.6 (99.3)		
Rest	944.4 (601.4)	761.4 (192.7)	840 (416.8)	0.07	0.4
Continuous	748 (127.3)	684.9 (191.7)	712 (166.5)		
Proportion correct		% (SD)			
Walk	92 (6.0)	93 (6.0)	92 (6.0)		
Rest	90 (6.0)	92 (5.0)	92 (5.0)	0.6	0.7
Continuous	91 (6.0)	90 (8.0)	91 (7.0)		
Kill/death ratio		KDR (SD)			
Walk	2.0 (1.2)	2.8 (2.3)	2.5 (2.0)		
Rest	1.9 (1.2)	2.6 (2.2)	2.3 (1.9)	0.8	0.5
Continuous	2.1 (1.2)	2.2 (1.6)	2.2 (1.4)		
Percentage of games won		% (SD)			
Walk	40.2 (27.7)	65.4 (20.1)	53.8 (26.4)		
Rest	38.3 (37.1)	51.1 (35.5)	45.2 (35.3)	0.6	0.4
Continuous	53.5 (10.1)	53 (18.7)	53.2 (14.7)		

*Significance.

RPE, rate of perceived exertion.

Table 3 Participants' perception data on each condition

How do you believe the 6min walk break impacted your gaming performance?					
Positively helped (%)	Negatively impacted (%)	No impact (%)		Representative positively helped comment:	Representative negatively impacted comment:
73.9	8.7	17.4		'It was good to take a break, but I think its active nature helped me stay prepared physically while offering me a more mental break.'	'It was a light movement and didn't fatigue me, but did break focus on the game.'
How do you believe the 6min rest break impacted your gaming performance?					
39.1	26.1	34.8		'I treated it like meditation! I focused and reflected on the previous games to try and prepare myself better for the following ones.'	'While the 6 -minute rest itself felt great, when I got back to my computer, I felt slow and lethargic, and it took me a while to get back into the game and warmup again.'
Which of the following do you think is most effective to help gaming performance?					
Walking break (%)	Rest break (%)	Continuous play (%)	No difference (%)	Representative walking break preference comments:	Representative rest break preference comment:
52.2	21.7	21.7	4.3	'I can't tell exactly why, but physically moving my body helped me feel more refreshed when I started the game again vs when I rested on my bed.'	'The lying down rest allowed me to more quickly relax after being fairly tense during play, which made the 'mental reset' feel more impactful on [future] play.'
				'(The) walking break definitely has the best impact on gaming performance. It helps you clear your mind while doing something physical. Even if you are walking slowly, it helps you calm down and forget the high pressure from the gaming environment. Your brain isn't going overboard anymore.'	Representative continuous play preference comment: 'No break allows [you] to stay in the zone and keeps you warmed up. Pro esports players have been caught taking Adderall so that they can stay in-game longer. Dedicating the most amount of time possible is the only way to get better at a game. It [is] exactly like a real sport.'

performance. Most commonly noted was the walk provided a good mental break, while half commented on its effectiveness of being physically active.

Responses were more varied regarding whether participants perceived the 6min laying down rest break impacted gaming performance as under 40% felt it positively helped. Participants who perceived that the rest break negatively hurt performance commonly noted that the rest made them sleepy, lethargic and slowed them.

When asked, 'Which of the following do you think is most effective to help gaming performance?' over half preferred the walking break. Common themes across participants who favoured the walking break perceived that the walk helped them provide an active break for their body and mind while at the same time physically preparing them for the next gaming session. Participants who favoured no break felt this helped keep in-game focus and consistent performance, with multiple participants noting that many professional esports players take Adderall for this very purpose. Adderall (generic name: amphetamine, dextroamphetamine mixed salts) is a prescription medication that belongs to a class of drugs known as central nervous system stimulants. It is typically prescribed to treat symptoms of attention deficit and hyperactivity disorder (ADHD) and impulse control. In people who do not suffer from ADHD, it produces

excess dopamine in the brain that can create increased energy levels and euphoria. Recreation abuse can lead to dangerous health effects²² (table 3).

DISCUSSION

This study was conducted virtually due to the lockdown regulations imposed globally from the COVID-19 pandemic during July through December 2020, comparing a 6min active break, a 6min passive break and no break on competitive FPS player performance and executive function. It is the first to demonstrate that an active break improves executive function compared with a passive (ie, rest) break while not impacting game performance. Interestingly, the continuous play (no break) performed superior to the resting break. Hence, a resting break may be a detriment to esports players.

The complexity and fast-paced demands of FPS gameplay place a significant demand on attention, cognition, working memory and executive function.^{1 2} In gaming, on a neural basis, elite esports players demonstrate enhanced cognitive control and attention.^{2 23} These cognitive demands elicit a sympathetic nervous system response presented by heart rate variability, heart rate fluctuations, respiratory rate increases, ventilation changes and blood pressure changes.^{3 11} This type of

demand may lead to mental fatigue, cognitive decline and, possibly, poor performance over time.

This project studied FPS gamers ranked at a highly competitive level. FPS games require rapid speed and reaction time, fine motor hand–eye coordination and demand high amounts of executive function and simultaneous actions.³ FPS gameplay also facilitates HR variability, HR fluctuations and increased cortisol levels.^{1 3 11} Finally, 2 hours of continuous esports gameplay have resulted in less accuracy and more impulsivity.¹¹ Given the cognitive demands required for high-level esports and the multiple hours of being seated, it is of interest to players and health professionals to incorporate practical ways to improve on performance while also improving health. To date, there are no studies that have comprehensively evaluated the physiological parameters in gamers. Therefore, the mechanisms described below of the underlying effects of prolonged sitting are based on previous studies in other populations and have been well established.

Cerebral blood flow and prolonged sitting

The middle cerebral artery (MCA) accounts for 70%–80% of the brain's perfusion. In healthy individuals who were not gamers, uninterrupted sitting for 4 hours caused a significant decrease in MCA blood flow velocity to 1.4–3.2 cm/s.¹⁰ This may not seem relevant, but this decline has been correlated to decreased focus and fatigue. Simply taking a 2 min light walking break every 30 min prevented these declines and improved cerebral autoregulation.¹⁰ Moreover, Wennberg *et al* found that 3 min of light walking, following 30 min of being seated, reduced fatigue and improved cognition in overweight adults.¹³ Although we were unable to collect biological variables in this study, we demonstrated an improvement in decision-making and impulsivity following a 6 min light walking break at the 60 min marker.

Endothelial function and prolonged sitting

Thrombotic events are concern in gamers despite age or activity level.^{5 7} The underpinning mechanism resulting in DVTs is endothelial function changes and blood flow, resulting from bouts of prolonged sitting. Following 1 hour of sitting, there is a significant reduction in superficial femoral artery flow-mediated dilation and a decrease in popliteal flow-mediated dilation that can last up to 3 hours or more.²⁴ Furthermore, endothelial changes and blood volume changes create an environment that can create blood pooling and more dangerous DVTs or PE. However, these blunted and vascular impairments caused by prolonged sitting were reversed with very light short bouts of activity.²⁵

Exercise intensity

De Las Heras *et al* exercised gamers using HIIT for 15 min at an RPE of 15.17 (0.34), which translates to working 'hard' or 'heavy'.²⁶ The average RPE for participants in the walking condition in this study was 10.5 (2.8), which

translates to 'light' intensity effort. Interestingly, the RPE for gaming was higher than the RPE for the walking break. The average perceived intensity level of gameplay was 13.5 (1.2), which is 'somewhat hard', further demonstrating the perceived demands of gaming.¹⁸ This study demonstrated improvement in cognitive abilities with as little as 6 min of light movement. Additionally, 73.9% of participants perceived that the active walking break positively helped their gaming performance. Based on the results of the IPAQ, there was no relationship between physical activity level and preference for a walking break.

Limitations

There are several limitations to this study. To collect data during the lockdowns of a pandemic, compromises had to be made. Collecting valid objective biometric data proved to be difficult and not feasible. Therefore, the walking effort was determined using the Borg RPE scale. Although this scale is validated, self-report bias may exist. The nature of the online data collection may have impacted how subjects conducted the tests without being in a testing environment. However, this is more reflective of a typical gaming environment than conducting the tests in a lab, which may have increased external validity. Results indicated no study intervention arm significantly impacted player win/loss rate or KDR. Still, other extraneous factors may also impact this (eg, quality of opponent or teammate gameplay, varying maps across games etc). Although there were no executive function changes seen between genders, the physiological changes from prolonged gaming while improving executive function could not be tested in this cohort.

CONCLUSION

This study has several implications. First, gaming performance and executive function were investigated in relation to an active 6 min break and a passive 6 min break, compared with continuous gameplay. While either intervention did not impact gaming performance, the active break showed an increase in speed with no change in accuracy, whereas the passive break had no change. Continuous play was slightly better than the resting break. Second, this is the first study to compare competitive gamers by gender in terms of executive function and gaming performance. Finally, this study showed the efficacy of conducting a virtual clinical trial. This is important in the gaming environment for a few reasons: (1) many investigators do not have easy physical access to esports players and (2) in cases of a pandemic or social distancing, there are valid and effective tools that can be used to assess outcomes virtually.

There have been several calls for improving gamers' health, with exercise being the primary focus.^{26–29} However, there may be a fair misconception that if one exercises regularly, one is not prone to negative health ramifications of prolonged sitting. Being less sedentary with frequent breaks may have a greater health impact than increasing exercise.⁸ This study provides evidence

that a 6min walking break improved executive function following a single bout of prolonged gaming and that an active break was preferred compared with a resting break. These findings suggest further investigation into multiple bouts of prolonged gaming to further understand the long-term implications an active break may have in competitive gamers.

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